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IN-SPACE PROPELLANT
LOGISTICS AND SAFETY

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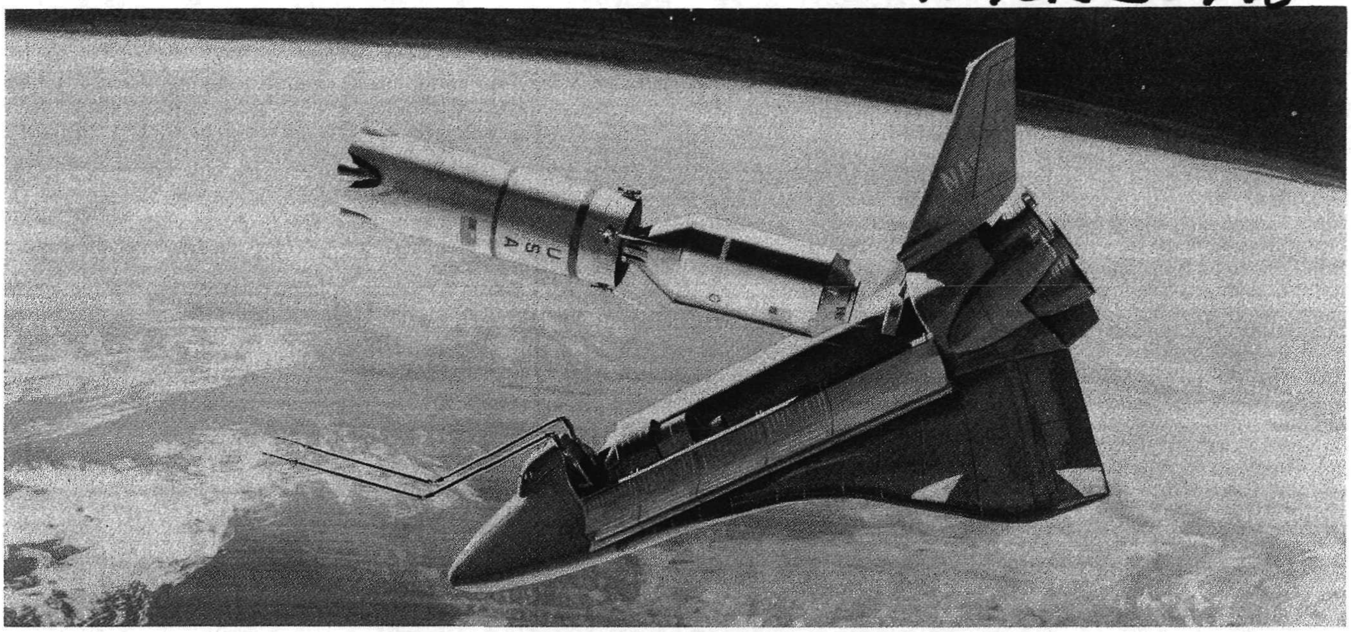

IN-SPACE PROPELLANT SYSTEMS SAFETY

Volume II

SYSTEM SAFETY GUIDELINES AND REQUIREMENTS

Space Division
North American Rockwell

12214 Lakewood Boulevard, Downey, California 90241

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FOREWORD

This In-Space Propellant Logistics and Safety Study was performed by the Space Division of North American Rockwell Corporation for the National Aeronautics and Space Administration, Marshall Space Flight Center, under Contract NAS8-27692. The study was a twelve-month effort initiated on June 25, 1971, and completed on June 23, 1972.

The study was conducted as two separate, but related projects. One project addressed the systems and operational problems associated with the transport, transfer, and storage of cryogenic propellants in low earth orbits, while the other project addressed the safety problems connected with in-space propellant logistics operations. Correlation between the two projects was maintained by including safety considerations resulting from the System Safety Analysis in the trade studies and evaluations of alternate operating concepts in the Systems/Operations Analysis.

Walter E. Whitacre of Marshall Space Flight Center, Advanced Systems Analysis Office, was the Contracting Officer's Representative and provided technical direction to the overall contract and to the Systems/Operations Analysis project; Walter Stafford of the same office provided technical direction to the System Safety Analysis project. The contractor effort was under the direction of Robert E. Sexton, Program Manager; the Systems/Operations Analysis effort was led by Robert L. Moore and the System Safety Analysis effort was led by William E. Plaisted. Key technical contributors were G. F. Ruff, System Safety Analysis and Trade Studies, and J. R. Cook, Literature Review, Preventive Measures, and Guidelines and Requirements.

This document is Volume II of the following three volumes which contain the System Safety Analysis.

Volume I	Executive Summary	(SD 72-SA-0054-1)
Volume II	System Safety Guidelines and Requirements	(SD 72-SA-0054-2)
Volume III	System Safety Analysis	(SD 72-SA-0054-3)

The results of the Systems/Operations Analysis portion of the study are contained in the following five volumes:

Volume I	Executive Summary	(SD 72-SA-0053-1)
Volume II	Technical Report	(SD 72-SA-0053-2)

Volume III	Trade Studies	(SD 72-SA-0053-3)
Volume IV	Project Planning Data	(SD 72-SA-0053-4)
Volume V	Cost Estimates	(SD 72-SA-0053-5)

This volume contains the guidelines and requirements to be applied to the design and operation of systems to transport propellants into space for subsequent use by another vehicle, to store propellants in space, or to transfer propellants from one element to another in space. It identifies two distinct methods of using the Guidelines and Requirements. The first would use them to define a safe concept of propellant delivery, and the second would be to use them as a checklist to determine whether an established concept was a safe one.

CONTENTS

1.0 INTRODUCTION

This volume of the final report contains detailed system safety guidelines/requirements (GLR's) developed during the course of the study. Each GLR describes a safety measure which is suggested as a means of eliminating or reducing a particular hazard, or group of hazards, to an acceptable level, and which, if followed would tend to increase the level of safety in supplying propellants to a user in orbit.

The development of GLR's was intended to serve two goals. The first was to identify those actions that should be taken to make propellant logistics operations as safe as possible. The second was to serve as a checklist to verify that these actions had been taken in the design and operation of this and similar programs, or that they had been considered and rejected.

The safety measures described in the GLR's are directed toward the prevention of hazards, the avoidance of undesired events, and the protection of the crew. Specific corrective action is, to a large measure, dependent on the state of events at the time of occurrence, the condition of the hardware after occurrence of the hazard, and upon the configuration of the systems in total. Measures for corrective action must be developed when the configuration of the system has been defined and the operational procedures are being written.

The guidelines/requirements take into account the results of the analysis of all the preventive measures taken against all the hazards that were identified. The study concentrated on propellant handling systems and operations in orbit. Hazards associated with ground and launch operations have also been studied and reported elsewhere; only such ground operations that would be unique to propellant logistics are reported here. These unique operations are concerned primarily with the use of slush propellants.

Several of the GLR's rely on the presence of monitoring devices for their execution. Section 5.3 of Volume III, "Monitoring Devices," contains a listing and a more detailed discussion of the need for these devices.

Each GLR appears only once and is numbered in serial with the others. The first 48 GLR's are numbered in sequence in the order in which they would be applied during pre-launch, ascent, deployment, docking, transfer, retrieval, and re-entry. GLR's 49 through 63 apply to all propellant logistics operations. Examples of their application to safety-critical propellant logistics operations are given.

2.0 DERIVATION OF GUIDELINES/REQUIREMENTS (GLR)

As in-space propellant logistics operations were analyzed for system safety, each hazard was identified and was entered on a hazard analysis sheet (Figure 2.0-1). The conditions leading to and the effects of the hazard were presented in the hazard description/effects block.

Preventive measures to be applied to eliminate the hazard or to reduce it to an acceptable level are presented in the action recommended block of the sheet. These measures are specific to the hazard postulated, with the stated systems being operated under the conditions stated. The goals of the preventive measures were practical solutions, using methods and techniques that have been proven successful in the past to solve similar problems with existing state-of-the-art. Extrapolations of the state-of-the-art have been identified.

The preventive measures provided the basis for the development of GLR's. The measures were grouped under headings that also served as titles for individual GLR's. Each preventive measure developed has been included in at least one generalized GLR.

2.1 GLR DESCRIPTION

2.1.1 A GLR sheet is shown in Figure 2.1.1-1. A description of each of the elements composing this sheet follows.

2.1.1.1 Number

The number was assigned in sequential order of use during a normal launch, orbital operation, and re-entry. The assigned number is used as an identifier throughout this volume.

2.1.1.2 Hazard Group

There were 12 hazard groups used in the study. These are representative of the hazards which could be broadly grouped from the various phases of the missions and operations of the representative orbital propellant logistic concept.

Hazard Group 1 - Fire/Explosion/Implosion

Group 1 includes hazards created by chemical reactions, catalytic action, frictional effects, or other heat generating principles. It further includes explosions initiated by fire or spark and those which are not necessarily fire initiated, such as overpressurization; instantaneous release of high pressures by container fracture; or reactions in ambient conditions where gaseous hydrogen and oxygen are combined in proportions of 4 and 2 percent by volume or greater and the resulting mixture is subjected to pressures of 2 mm of Mercury or more and is subjected to an initiation source, such as a catalytic reaction with a nickel, zirconium, etc., impact or spark.

Figure 2.1.1-1

ISPLS GUIDELINE/REQUIREMENT

NO.

HAZARD GROUP:

MISSION PHASE:

APPLICABLE SUBSYSTEMS:

GUIDELINE TITLE:

STATEMENT:

(SAMPLE GLR SHEET)

REMARKS:

FIN 160

REFERENCES:

CROSS REFERENCES:

CONTRACT ____________

LOCATION/SITE INVOLVED ____________

HAZARD ANALYSIS

PAGE ____ OF ____
DATE ____________
REV ____________

END ITEM	SUBSYSTEM	SUBSYSTEM IDENT NO.
OPERATION/PHASE		OP. IDENT. NO.
HAZARD GROUP		HAZARD GRP. CODE
REFERENCES		AUTHORITY

HAZARD DESCRIPTION/ EFFECTS

(SAMPLE HAZARD ANALYSIS SHEET)

ORIGINATOR	GROUP	EXT.	HAZARD CLASS

COPIES TO: STRUCTURAL ____ MECHANICAL ____ MATERIALS ____ GSE ____ OTHER ____

AVIONICS ____ PROPULSION ____ VEHICLE SUPPORT ____ FACILITIES ____ PAYLOAD ____ SYS SAFETY ____

ACTION RECOMMENDED:

REQUIRED PRIOR TO	RECOMMENDED BY	GROUP	EXT.	HAZARD REDUCED TO

Figure 2.0-1

Implosion includes those hazards in which an adverse ΔP is created across a structure (tank) by the reduction of internal pressure during such activities as drainage of fluid from a locked up volume, cryo-pumping, or venting to vacuum and locking the tank up for re-entry into the earth's atmosphere.

Hazard Group 2 - Reduced Integrity of Structure or Equipment

Group 2 includes conditions which subject a structure or equipment to some level of degradation, such as possible adverse stress due to exposure resulting from temperature extremes, interaction between fluids and materials, reduction in critical characteristics or materials capability, functional degradation due to loss of supporting equipment, and out of sequence operations.

Hazard Group 3 - Contamination

Group 3 includes hazards related to those conditions producing or introducing contamination. The contamination ranges from traces to large particles, including products of combustion, ice crystals, and metal chips.

Hazard Group 4 - Corrosion

Group 4 includes those conditions which adversely damage personnel or material surfaces by chemical attack.

Hazard Group 5 - Toxicity

Group 5 includes hazards related to the production of a toxic substance which affects the human body adversely.

Hazard Group 6 - Heat and Temperature

Group 6 includes those conditions related to excursions of temperature ranging from extreme heat to extreme cold.

Hazard Group 7 - Loss of Thrust

Group 7 covers those cases where loss of thrust is experienced when it is needed for scheduled operations. In includes problems involved in main and auxiliary propulsion engines and propulsive vents.

Hazard Group 8 - Unscheduled Vehicle Impact

Group 8 includes impact hazards involving loss of target by the vehicle avionics or ground net; impact of meteoroid and/or space debris with the vehicle due to mechanical failures or delays in valve actuation for any reason; impact due to loss of docking aids or incorrect approach alignment; and impact from inadvertent misoperation of RCS, propulsive vents, etc. Manipulator related hazards, such as loss of TV and lighting, impact of the cargo with the structure, and damage caused by sloshing or unstabilizing effects are also included. Human error has been included in the group as related to impacts while is in manual control or commands are introduced for remote activation.

Hazard Group 9 - Loss of Attitude Control

Group 9 includes those hazards where the inability to achieve stabilization for any reason prevails, such as lack of or intermittent RCS operation and CG shift during rotation. This group also includes the conditions where application or release of tension loads causes instability within the configuration for any time duration without damping.

Hazard Group 10 - Loss of Habitable Environment

Group 10 includes any hazards which would render the manned volume unfit for unsuited occupancy, such as decompression by penetration, long-term leakage or seal failures which give unscheduled depletion of oxygen supply, contamination, heat, humidity, and loss of CO_2 control.

Hazard Group 11 - Loss of Communication

Group 11 includes loss of ability to send or receive programmed data under operational conditions. It encompasses radio, radar, laser, TV, and hard wire communications and necessary equipment, GSE, facilities, or satellites associated with the communication process.

Hazard Group 12 - Disturbances

Group 12 includes those conditions which can adversely affect stability conditions, such as sloshing and CG shift coupled with the dynamics of the vehicle or configuration, with RCS interaction, with tank inlet fluid momentum distorting the liquid surface, or with combinations initiating such conditions, including impact and wobble.

2.1.1.3 Mission Phase

The mission phase block describes briefly the operation or group of operations taking place when the hazard occurs that the GLR is to prevent. These phases or events are described below.

a. All will be used when the GLR applies to any propellant logistics operation that is performed on the ground, during ascent, or in orbit.

b. Deployment consists of those functional steps that are to be performed to remove a propellant logistics element from the transport vehicle.

c. Docking includes those operations performed to effect a mating, or joining, of two orbiting vehicles.

d. EVA (extra vehicular activity) is that activity taking place outside the prime vehicle within a separate life support system (suit) that may or may not be connected by umbilicals to the prime vehicle.

e. Ground operations are those steps or functions performed on the ground to support the launch of a vehicle or to render assistance to an orbiting vehicle.

f. Launch consists of those steps taken to transport a propellant logistics element from the ground into orbit.

g. Manned operations are those functions performed with human assistance.

h. Manned orbital operations are those functions performed in orbit with human assistance.

i. Orbital assembly is the construction, in orbit, of a large assembly of elements that are transported to orbit individually by the transport vehicle.

j. Orbital maintenance refers to those repairs made to a vehicle while in orbit. Maintenance by machine is not ruled out, but the prime concern in this type event is the performance of orbital maintenance by man.

k. Orbital operations are those steps or functions performed upon or with orbiting propellant logistics elements.

l. Prelaunch activity is that activity performed upon propellant logistics elements to prepare them for the launch operation.

m. Propellant transfer is the act of transferring propellants from one tank to another. In the modular case, it would be the transposition of a propellant module from one position to another.

n. Re-entry is the act of transporting a vehicle from orbit to earth. Sometimes de-orbit is used interchangeably with re-entry.

o. Retrieval includes all those steps taken to remove an orbital element from a stationkeeping mode alongside a transport vehicle and to place the element in the cargo bay and prepare it for re-entry.

p. Sub-orbital abort consists of those steps taken from the time that a transport vehicle fails to achieve earth orbit, for whatever reason, until the transport vehicle lands.

2.1.1.4 Applicable Subsystems

In this block will be entered the systems or functions that the stated guideline will affect. The terms used are in common use throughout the industry and need not be defined here.

2.1.1.5 Guideline Title

This is the verbal identifier for the GLR.

2.1.1.6 Guideline Statement

This block contains the full GLR statement.

2.1.1.7 Remarks

A narrative statement of supporting data, further justification, or elaboration of the GLR statement is entered in this block.

2.1.1.8 References

The source of information that made the guideline statement necessary is entered in this block. Hazard analysis references will be entered as HA 12, which corresponds to Hazard Analysis Sheet 12. Literature references are in parenthesis and (69) would refer to that numbered document listed in Appendix H of Volume III of this report.

2.1.1.9 Cross References

The numbers of the additional GLR that support the guideline statement are entered in this block.

3.0 APPLICATION OF SYSTEM SAFETY GUIDELINES/REQUIREMENTS

Guidelines/Requirements (GLR's) are applied according to two methods: Examples of the two methods are developed in this section. Figure 4.1-1 presents the results of this development. GLR's are identified as applicable to the design or operational phase, or both, in the column headed "Type of GLR" in Figure 4.1-1.

3.1 CONCEPT DEVELOPMENT

In the development of a concept, the GLR can be used to provide the optimum degree of safety in propellant logistics design and operations. One of the requirements of the study was to develop GLR's for prelaunch and launch (including ascent), orbital operations and lunar operations. GLR's have been written for any concept developed for use in these three broad areas.

3.1.1 Prelaunch and Launch (Including Ascent)

The distinguishing features of this area of operations are the presence of gravity (earth gravity or that induced by acceleration) and an atmosphere that includes oxygen. The appropriate GLR's for the development of a concept to be used under these conditions are listed in Column 3.1.1 of Figure 4.1-1.

3.1.2 Orbital Operations (Including Earth and Lunar Orbit)

The distinguishing features of this area of operations are the absence or great reduction of gravity and atmosphere (including the absence of readily available oxygen). In the development of a concept to be used under these conditions, the GLR's that should be taken into consideration are listed in Column 3.1.2 of Figure 4.1-1.

3.1.3 Lunar Operations

The distinguishing features of operating on the lunar surface are the presence of a significant gravitational force and the absence or great reduction of atmosphere (including oxygen). In the development of a concept to be used in lunar operations, the GLR's that should be considered are listed in Column 3.1.3 of Figure 4.1-1.

3.2 DESIGN CHECKLIST

GLR's can be used to verify that the optimum degree of safety has been incorporated into existing designs, as demonstrated in Figure 3.2-1. This figure portrays several propellant logistics concepts and the different requirements of four orbital operations. The vertical columns have been numbered, and the horizontal rows have been alphabetized in such a way that A.2.2 would be the operation of "remote hard dock CIS to LSF" under the baseline concept. The development of Figure 3.2-1 is discussed in Section 2.1 of Volume III of this report.

Figure 3.2-1 In-Space Propellant Logistics Safety Critical Operations

	CONCEPT \ OPERATIONS	1 DEPLOYMENT	2 DOCKING	3 TRANSFER	4 RETRIEVAL
A	BASELINE	PROPELLANT TANK MODULE DEPLOYED BY MANIPULATORS FROM CARGO BAY	SHUTTLE SOFT DOCKS PROPELLANT TANK MODULE TO LSF REMOTE HARD DOCK CIS TO LSF	ROTATIONAL ACCELERATION OF LSF FOR PROPELLANT SETTLING - CIS/RNS - ORBITER UNATTACHED	PROPELLANT TANK RETRIEVAL--EMPLACEMENT IN CARGO BAY & DEORBIT OF ORBITER
B	ORBITER/ TUG/LSF		REMOTE HARD DOCK TUG/MODULE TO LSF		
C	BOOSTER/ ESS/LARGE PROPELLANT TANK		REMOTE HARD DOCK OF LARGE PROPEL-LANT TANK WITH CIS/RNS		
D	ORBITER TO ORBITER			FLEX LINES USED BY ATTACHING AT QD WITH USE OF MANIPULATORS POSITIVE DISPLACEMENT METHOD USED FOR PRO-PELLANT TRANSFER	
E	ORBITER TO TUG	PROPELLANT TANK MODULE DEPLOYED BY ROTATIONAL DEPLOYMENT MECHANISM		ROTATIONAL OR LINEAR ACCELERATION FOR PROPELLANT SETTLING WITH ORBITER ATTACHED	
F	ORBITER TO CIS/RNS		ORBITER HARD DOCKS PROPELLANT TANK MODULE TO CIS/RNS	LINEAR ACCELERATION FOR CIS/RNS/TANK MODULE PRO-PELLANT SETTLING WITH ORBITER NOT ATTACHED CAPILLARY FLUID CONTROL FOR CIS/RNS/TANK MODULE PROPELLANT TRANSFER	
G	ORBITER TO MODULAR CIS	PROPELLANT TANK MODULE DEPLOYED BY ROTATIONAL & MANIPULATOR MECHANISMS			

3.2.1 Guidelines/Requirements Common to all Orbital Operations

The GLR's that are common to any of the orbital operations in Figure 3.2-1 are listed in Column 3.2.1 of Figure 4.1-1.

3.2.2 Guidelines/Requirements Unique to Orbital Operations

The additional GLR's that apply to specific operations are tabulated in Figure 4.1-1. Reference is made to Figure 3.2-1 for the identification of the operation in progress.

3.2.2.1 A-1-1 Concept - Baseline

Operation - Propellant Tank Module Deployed by Manipulators from Cargo Bay

During this operation, the shuttle orbiter has delivered a propellant module to orbital altitude. The orbiting propellant depot has been assembled in orbit, and the shuttle is stationkeeping, with cargo bay doors open, and is ready to deliver a propellant module. Deployment will consist of those steps to be taken to sever the interface of the module and shuttle and to remove the module from the cargo bay by the use of manipulators.

Since this is largely a manual operation, common GLR 57 (Automatic Operation) is applicable to supporting systems; and common GLR's 49 (Crew Fatigue), 61 (Crew Training), and 62 (Procedures Development), are applicable.

Additions to the applicable common GLR's are listed in Column 3.2.2.1 of Figure 4.1-1.

3.2.2.2 A-2-1 Concept - Baseline

Operation - Shuttle Soft Docks Propellant Tank Module to LSF (Large Storage Facility)

During this operation, the shuttle is stationkeeping with the LSF, with the propellant module on the extended manipulator arms. The manipulator arms are used to soft dock the module and rigidize it to the LSF. Then the orbiter translates away from the LSF/module combination. Included in this operation is the requirement to maintain vehicle stability while the element is attached to the manipulator arms.

This operation is largely manual, since vehicle stability is critical. Common GLR 57 (Automatic Operations) is applicable to supporting systems and GLR 32 (Uncontrolled Oscillations), 33 (Fluid Sloshing, 34 (Non-Propulsive Vents), 49 (Crew Fatigue), 61 (Crew Training), and 62 (Procedures Development should be emphasized.

Additions to the common GLR that should be applied are listed in Column 3.2.2.2 of Figure 4.1-1.

3.2.2.3 A-2-2 Concept - Baseline

Operation - Remote Hard Dock CIS (Chemical Interorbital Shuttle) to LSF

During this operation, the CIS will automatically dock with no manned assistance. Of significance is the large mass of both vehicles. Additional consideration would be given to momentum and the possible excursion of residual CIS propellants from one end of the tank to the other during the docking impact. The passive vehicle is the LSF; the active vehicle is the CIS.

Since this is an unmanned operation, the GLR's that deal with the support of man in orbit do not apply. The common GLR's that should receive emphasis include 53 (Manual Override), 57 (Automatic Operations), 52 (Operations Monitor), and 63 (Malfunction Detection and Warning Devices).

Additions to the common GLR that should be applied are listed in Column 3.2.2.3 of Figure 4.1-1.

3.2.2.4 A-3-1 Concept - Baseline

Operation - Rotational Acceleration of LSF for Propellant Settling--CIS/RNS (Re-usable Nuclear Shuttle)--Orbiter Unattached

During this operation, the LSF and CIS/RNS have docked, the interface has been rigidized, and pretransfer operations have been completed. Rotational acceleration is initiated by firing the RCS of the coupled elements to achieve the necessary rotational speed to settle the propellants.

Since this is an automatic propellant transfer, automatic operations are emphasized. Common GLR's that should receive emphasis are 53 (Manual Override), 57 Automatic Operations, 52 (Operations Monitor), and 63 (Malfunction Detection and Warning Devices.

Additions to the common GLR's that should be applied are listed in Column 3.2.2.4 of Figure 4.1-1.

3.2.2.5 A-4-1 Concept - Baseline

Operation - Propellant Tank Retrieval--Emplacement in Cargo Bay and Deorbit of Orbiter

During this operation, the orbiter stationkeeps with the stable LSF, removes the empty module from the LSF, translates away, positions the module in the cargo bay, makes necessary verification tests, closes the doors and deorbits. The stability of the module while on the manipulator arms and the influence of residual propellants are primary concerns.

Retrieval operations are largely manual, and associated common GLR's will receive the same emphasis as in A-1-1 above. The preparation for deorbit and the deorbit phase are critical to the orbiter and crew, and the applicable GLR's are listed in Column 3.2.2.5 of Figure 4.1-1.

3.2.2.6 B-2-1 Concept - Orbiter/Tug/LSF

Operation - Remote Hard Dock Tug/Module to LSF

Once a baseline concept has been established, modifications to that baseline will introduce other hazards that must be countered with additional GLR's. The new elements that have been added by this operation are the remote automatic docking of a small mass (tug) to a large mass (LSF). The common GLR that should be emphasized is 32 (Uncontrolled Oscillations).

Additions to the common GLR that should be applied are listed in Column 3.2.2.6 of Figure 4.1-1.

3.2.2.7 C-2-1 Concept - Booster/ESS (Expendable Second Stage) Large Propellant Tank

Operation - Remote Hard Dock of Large Propellant Tank with CIS/RNS

The added operation is the remote, automatic docking of a large tank with another large mass (CIS/RNS) after the tank has been boosted by the ESS. Common GLR 32 (Uncontrolled Oscillations) should be emphasized.

Additions to the common GLR that should be applied are listed in Column 3.2.2.7 of Figure 4.1-1.

3.2.2.8 D-3-1 Concept - Orbiter to Orbiter

Operation - Flex Lines used by Attaching at QD (Quick Disconnect) with use of Manipulators

During this operation the additional elements are the stationkeeping of two orbiters and the use of manipulators to hook up flex lines in preparation for propellant transfer.

Common GLR's that should receive emphasis are 32 (Uncontrolled Oscillations), 29 (Ejected Material), 49 (Crew Fatigue), 61 (Crew Training), and 62 (Procedures Development).

3.2.2.9 D-3-2 Concept - Orbiter to Orbiter

Operation - Positive Displacement Method Used for Propellant Transfer

The additional element in this operation is the introduction of bladders or diaphragms for fluid expulsion. The requirement to maintain stabilization and orbiter spacing and the common GLR's are the same as for D-3-1 above.

Additions to the common GLR's that should be applied are listed in Column 3.2.2.9 of Figure 4.1-1.

3.2.2.10 E-1-1 Concept - Orbiter to Tug

Operation - Propellant Tank Module Deployed by Rotational Deployment Mechanism

During this operation, the rotation devices are introduced to deploy a propellant module out of the cargo bay of the shuttle. An item of concern is the lateral stability of the module while it is being rotated out of the cargo bay. The common GLR 32 (Uncontrolled Oscillations) should be emphasized.

Additions to the common GLR that should be applied are listed in Column 3.2.2.10 of Figure 4.1-1.

3.2.2.11 E-3-1 Concept - Orbiter to Tug

Operation - Rotational Acceleration for Propellant Settling with Orbiter Attached

For this operation, the orbiter remains attached to serve as a counterweight while propellants are transferred from a module to a tug. Of significance is the fact that the orbiter crew remains relatively inactive for long periods (ten-hour transfer time) and is subject to any instability introduced by the assembly that might be detrimental to human performance.

For this operation, common GLR's 32 (Uncontrolled Oscillations) and 49 (Crew Fatigue) should receive emphasis.

Additions to the common GLR's that should be applied are listed in Column 3.2.2.11 of Figure 4.1-1.

3.2.2.12 E-3-2 Concept - Orbiter to Tug

Operation - Linear Acceleration for Propellant Settling with Orbiter Attached

This combination introduces linear acceleration for extended periods with low-thrust engines. Again, the orbiter crew is relatively inactive for ten hours and subject to any instability introduced by the assembly that might be detrimental to human performance. Common GLR's that receive emphasis are 32 (Uncontrolled Oscillations, 50 (Redundancy), and 49 (Crew Fatigue).

Additions to the common GLR's that should be applied are listed in Column 3.2.2.12 of Figure 4.1-1.

3.2.2.13 F-2-1 Concept - Orbiter to CIS/RNS

Operation - Orbiter Hard Docks Propellant Tank Module to CIS/RNS

During this operation, the orbiter is required to stationkeep with a modular CIS, remove a module from the cargo bay and soft-dock it to the CIS, rigidize the module, and translate away. The requirement to maintain controlled orbiter spacing from the CIS makes the common GLR's 32 (Uncontrolled Oscillations) and 61 (Crew Training) especially important.

Additions to the common GLR's that should be applied are listed in Column 3.2.2.13 of Figure 4.1-1.

3.2.2.14 G-1-1 Concept - Orbiter to Modular CIS

Operation - Propellant Tank Module Deployed by Rotational and Manipulator Mechanisms

During this operation, the use of manipulators and rotational modes of deployment are combined. The common GLR's to be emphasized are 32 (Uncontrolled Oscillations), 61 (Crew Training), and 62 (Procedures Development).

Additions to the common GLR's that should be applied are listed in Column 3.2.2.14 of Figure 4.1-1.

3.2.2.15 F-3-1 Concept - Orbiter to CIS/RNS

Operation - Linear Acceleration for CIS/RNS/Tank Module Propellant Settling with Orbiter not Attached

During this operation, the assembled CIS or RNS with the tank module attached is linearly accelerated for long periods of time. The common GLR's to be emphasized are the same as for E-3-2.

The additions to the common GLR's that should be applied are listed in Column 3.2.2.15 of Figure 4.1-1.

3.2.2.16 F-3-2 Concept - Orbiter to CIS/RNS

Operation - Capillary Fluid Control for CIS/RNS Tank Module Propellant Transfer

During this operation, the use of capillary devices is introduced for propellant settling. Since these devices are static in their operation, no one common GLR would receive special emphasis.

Applicable GLR's are listed in Column 3.2.2.16 of Figure 4.1-1.

4.0 IN-SPACE PROPELLANT SYSTEM SAFETY (ISPSS) GUIDELINES/REQUIREMENTS

4.1 SUMMARY OF THE APPLICATION OF GUIDELINES/REQUIREMENTS

Figure 4.1-1 is a summary of the results of the preceding sections.

This figure contains a complete listing of the GLR's by number and title. The first two columns headed by "Type of GLR" indicate whether the GLR would be applied during the design or operational phase, or both. An "X" at the intersection of the rows and columns indicates the applicability of the particular GLR during that phase.

The columns headed by 3.1 indicate the applicability of the GLR during concept development.

The columns headed by 3.2 indicate the applicability of the GLR as a checklist to determine whether the concept is optimized for safety. An "O" in these rows and columns indicates a GLR that would be common to any orbital operation that must be emphasized for a specific orbital mission. These specific orbital missions are described in the paragraph number at the head of the column.

Figure 4.1-1
Summary of the Application of In-Space System Safety (ISPSS) Guidelines/Requirements

GUIDELINE/REQUIREMENT	Type of GLR		3.1 Concept Development			3.2 Design Checklist																
	Design	Operational	3.1.1	3.1.2	3.1.3	3.2.1	3.2.2.1	3.2.2.2	3.2.2.3	3.2.2.4	3.2.2.5	3.2.2.6	3.2.2.7	3.2.2.8	3.2.2.9	3.2.2.10	3.2.2.11	3.2.2.12	3.2.2.13	3.2.2.14	3.2.2.15	3.2.2.16
1. Proof Pressure Test		X	X																			
2. Installation Verification	X	X	X	X	X			X				X	X						X			
3. Propellant Leakage in Cargo Bay	X	X	X																			
4. Fluid Line Interconnect Verification	X	X	X	X	X			X	X	X	X	X	X	X	X		X	X	X		X	X
5. Electrical Interconnect Verification	X	X	X	X	X			X	X	X	X	X	X				X	X	X		X	X
6. Cargo Bay Fire Detectors	X		X																			
7. Cargo Bay Hazardous Gas Detectors	X		X																			
8. Ground Purge	X	X	X																			
9. Expansion of Melting Cryogen	X		X	X	X	X																
10. Solid/Liquid Separation in Slush Cryogens	X		X		X																	
11. Solid Fraction Measurement in Slush	X		X	X	X					X							X	X			X	
12. Loading, Unloading Propellants	X		X		X																	
13. Negative Tank Pressure	X	X	X																			
14. Sub-Orbital Abort	X		X																			
15. Vent/Dump System	X		X	X	X	X																
16. Contamination of LSS	X		X	X	X		X	X			X			X	X	X	X		X	X		
17. EVA Operations		X		X	X																	
18. Manned Activation	X			X	X																	
19. Maintenance Crew Support	X			X	X																	
20. Propellant Logistics Element Attach Points	X			X	X									X	X							
21. Maintenance in Restricted Areas		X		X	X																	
22. Power Removal Prior to Connector Operation	X	X	X	X	X					X				X	X		X					X
23. Reaction Control Interface	X	X		X				X	X			X	X						X			
24. Docking to Unstable Vehicles		X		X				X				X	X						X			
25. Manipulator Operation		X		X			X				X			X						X		
26. Operating with Slush Propellant	X			X	X				X	X		X	X								X	X
27. Evaporative Freezing of Liquids	X	X		X	X	X																
28. Clogging of Manifolds with Frozen Propellant	X			X	X	X																
29. Ejected Material	X	X	X	X	X	X					X			0	0							
30. Protection of Visual Aids	X	X		X	X		X	X			X		X	X	X	X	X		X	X		X
31. RCS Capability	X			X						X				X	X		X					X
32. Uncontrolled Oscillations	X			X		X		0				0	0	0	0	0	0	0	0	0	0	
33. Fluid Sloshing	X			X		X		0														
34. Non-Propulsive Vents	X			X		X		0														
35. Orbiting Debris		X		X	X	X																
36. Meteoroid Shields	X			X	X	X																
37. Childown	X	X	X	X	X					X							X	X			X	X
38. Velocity Head Suppression	X		X	X	X					X				X	X		X	X			X	X
39. Vapor Pull-Through	X			X	X					X				X	X			X			X	X
40. GG Safety Devices	X			X	X					X											X	
41. RCS and GG Accumulator	X			X						X								X			X	X
42. Propellant Transfer Pumps	X			X						X								X			X	X
43. Rotating Machinery	X		X	X	X					X								X			X	
44. Capillary Propellant Settling	X	X		X																		X
45. Strainers and Filters	X		X	X	X					X				X	X			X			X	X
46. Sublimation of Solid Propellant		X		X	X						X											
47. Orbital Leak Checks		X		X	X					X				X	X		X	X			X	X
48. Orbital Propellant Dump		X		X							X											
49. Crew Fatigue		X	X	X	X	X	0	0			0			0	0		0	0			0	
50. Redundancy	X		X	X	X	X												0			0	
51. Confined Compartments	X		X	X	X	X																
52. Operations Monitor	X	X	X	X	X	X			0	0												
53. Manual Override of Automatic Functions	X		X	X	X	X			0	0												
54. Systems Interlocks	X		X	X	X	X																
55. Monitoring Quantity of Propellant	X		X	X	X	X																
56. Materials Compatibility	X		X	X	X	X																
57. Automatic Operation	X		X	X	X	X			0	0												
58. Pressure Relief	X		X	X	X	X																
59. Communications Blackout	X			X		X																
60. Man-Compatibility		X	X	X	X		X	X			X			X	X	X		X	X	X	X	
61. Crew Training		X	X	X	X	X	0	0			0			0	0				0	0		
62. Procedures Development		X	X	X	X	X	0	0			0			0	0					0		
63. Malfunction Detection and Warning Devices	X		X	X	X	X			0	0												

NOTE: A "0" entered in these columns indicates that the Common GLR from Column 3.2.1 should receive particular emphasis.

ISPSS GUIDELINE/REQUIREMENT

NO. 1

HAZARD GROUP: 2

MISSION PHASE: Pre-launch

APPLICABLE SUBSYSTEMS: Pressurized Systems

GUIDELINE TITLE: Proof Pressure Tests

STATEMENT: ALL PRESSURIZED CONTAINERS SHALL BE PROOF-TESTED AFTER FABRICATION TO LEVELS GREATER THAN THEIR OPERATING PRESSURE (HYDROSTAT 1-1/2 TIMES OPERATING, PNEUMOSTAT 1-1/4 TIMES OPERATING).

REMARKS: The proof test is considered necessary as the final confirmation of design and fabrication of pressure vessels. At least one representative unit will be life-tested by pressurizing to operating level or above and relieving the pressure to ambient for as many cycles as the unit is to be exposed in service.

FIN 160

REFERENCES: HA 11, 12, 38, 44, 49, 117

CROSS REFERENCES:

ISPSS GUIDELINE/REQUIREMENT

NO. 2

HAZARD GROUP: 2

MISSION PHASE: Pre-launch, Retrieval

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Installation Verification

STATEMENT: AFTER THE INSTALLATION OF A PROPELLANT LOGICTICS ELEMENT IN THE CARGO BAY OF THE SHUTTLE, VISUAL INSPECTION, LEAK TEST AND ELECTRICAL TESTS SHALL BE CONDUCTED TO VERIFY THAT THE ELEMENT HAS NOT BEEN DAMAGED BY THE INSTALLATION.

REMARKS: Unnoticed damage to insulation, structures or other systems could occur on ground installation or orbital retrieval and emplacement of the element in the shuttle cargo bay. Insulation damage could lead to intolerable propellant boil-off and other systems damage could lead to mission loss from other sources. The post-installation tests should be used to verify that any system to be used in subsequent operations will successfully perform its function.

FIN 160

REFERENCES: HA8

CROSS REFERENCES: 63

ISPSS GUIDELINE/REQUIREMENT

NO. 3

HAZARD GROUP: 1

MISSION PHASE: Pre-launch, Launch, Retrieval

APPLICABLE SUBSYSTEMS: Propellant Tanks, Shuttle Interface

GUIDELINE TITLE: Propellant Leakage into Cargo Bay of Shuttle

STATEMENT: PROPELLANT LOGISTICS ELEMENTS SHALL BE LEAK CHECKED TO VERIFY THAT THE LEAKAGE OF HYDROGEN SYSTEMS IS WITHIN SPECIFICATION TOLERANCE PRIOR TO PRE-LAUNCH LOADING AND PRIOR TO RE-ENTRY FROM ORBIT.

REMARKS: For a complete discussion of the hydrogen leakage problem, refer to Vol III Section 4.2. The following summarizes the results of this analysis and details the minimum steps that need to be taken to reduce this hazard.

On the Ground:

1. Perform a leak check on the propellant logistics element prior to placing it in the cargo bay.
2. Verify that the element/orbiter interface is leak-tight and that no leaks developed in the element during installation.
3. Provide a ground, inert gas purge to dilute H_2 from credible leaks to less than 4% by volume in the cargo bay.
4. Provide hydrogen, oxygen and fire detectors for the cargo bay.
5. Provide emergency propellant un-loading capability.

Prior to De-Orbit:

1. Perform a visual inspection & leak-check of element by TV or through the view ports, prior to retrieval. Liquid leaks in a hard vacuum are highly visible.
2. Inspect cargo bay for evidence of propellant "ice."
3. Install element in cargo bay, leak check element, & interface between transport vehicle and element.
4. Dump residual propellants after settling before or after installation.
5. Verify tank pressure is within structural limits of atmospheric pressure. This series of leak checks will ensure that any leaks greater than normal are detected. Normal leakage is not hazardous for the currently considered propellant logistics elements.

REFERENCES: VOL. III, Sec. 4.2.5 (15), (16), (17), (18), (20), (21)

CROSS REFERENCES: 2, 4, 5, 6, 7, 46, 47, 48, 51, 55, 63

ISPSS GUIDELINE/REQUIREMENT

NO. 4

HAZARD GROUP: 1

MISSION PHASE: Pre-launch, Docking, Retrieval

APPLICABLE SUBSYSTEMS: Fluid Line Interface Connections

GUIDELINE TITLE: Fluid Line Interconnect Verification

STATEMENT: PROVIDE A MEANS TO VERIFY THAT THE FLUID LINES OF PROPELLANT LOGISTICS ELEMENTS ARE CONNECTED AND THAT THE INTERFACE IS LEAK FREE BEFORE FLUIDS ARE TRANSFERRED.

REMARKS: The fluid connections between propellant logistics elements and between the module and shuttle are critical to efficient propellant transfer and safe orbiter return. A partially engaged or leaking fluid interface connection could lead to the loss of the propellant logistics mission or to fire/explosion in the cargo bay.

When the fluid lines are connected and rigidized, the monitor shall have verification of this fact. Before fluid is transferred, or before re-entry of the shuttle, the fluid connection shall be verified to be free of hazardous leaks.

REFERENCES: HA 90, 112, 116

CROSS REFERENCES: 47, 63

ISPSS GUIDELINE/REQUIREMENT

NO. 5

HAZARD GROUP: 2

MISSION PHASE: Pre-launch, Docking, Retrieval

APPLICABLE SUBSYSTEMS: Electrical Interface Connections

GUIDELINE TITLE: Electrical Line Interconnect Verification

STATEMENT: PROVIDE A MEANS TO VERIFY THAT THE ELECTRICAL INTERFACE BETWEEN PROPELLANT LOGISTICS ELEMENTS ARE ATTACHED AND THAT THE CONNECTION PROVIDES ELECTRICAL ISOLATION BETWEEN CONDUCTORS AND CONTINUITY WITHIN CONDUCTORS BEFORE PROCEEDING TO SUBSEQUENT OPERATIONS.

REMARKS: The electrical connections that will transmit data and control signals between propellant logistics elements and between the module and shuttle is critical to propellant transfer and safe orbiter return. A partially engaged electrical interface or intermittent contact or shorts between conductors could lead to loss of control of subsequent operations or loss of data with which to conduct subsequent operations.

When the electrical interface is connected and rigidized the monitor shall have verification of this fact and prior to subsequent operations tests shall be conducted to verify that all electrical conductors have been properly mated.

FIN 160

REFERENCES: HA 35, 90, 127

CROSS REFERENCES: 52, 63

ISPSS GUIDELINE/REQUIREMENT

NO. 6

HAZARD GROUP: 1

MISSION PHASE: Ground Operations

APPLICABLE SUBSYSTEMS: Caution and Warning System

GUIDELINE TITLE: Cargo Bay Fire Detectors

STATEMENT: FIRE DETECTORS SHALL BE PROVIDED FOR THE CARGO BAY OF THE SHUTTLE DURING PROPELLANT LOGISTICS OPERATIONS.

REMARKS:

Fire detectors that indicate rising temperature in time to take corrective action and prevent or minimize fire damage must be provided for the cargo bay when it contains a propellant logistics element.

FIN 160

REFERENCES: HA 2

CROSS REFERENCES: 63

ISPSS GUIDELINE/REQUIREMENT

NO. 7

HAZARD GROUP: 1

MISSION PHASE: Ground Operations

APPLICABLE SUBSYSTEMS: Caution and Warning System

GUIDELINE TITLE: Cargo Bay Hazardous Gas Detectors

STATEMENT:

GAS DETECTORS SHALL BE PROVIDED TO INDICATE THE CONCENTRATION OF COMBUSTIBLE GAS IN THE CARGO BAY

REMARKS:

During pre-launch operations the gas detectors would provide information on the presence of leaks that had developed during the loading operation. Procedures shall be developed that will detail the corrective action to be taken to prevent or minimize fire damage that could occur as a result of the presence of the hazardous gas.

FIN 160

REFERENCES: HA 2

CROSS REFERENCES: 63

ISPSS GUIDELINE/REQUIREMENT

NO. 8

HAZARD GROUP: 1

MISSION PHASE: Pre-launch

APPLICABLE SUBSYSTEMS: Confined Compartments

GUIDELINE TITLE: Ground Purge

STATEMENT: ALL CONFINED VOLUMES OF PROPELLANT LOGISTICS ELEMENTS SHALL BE PURGED WITH AN INERT GAS TO PREVENT THE ACCUMULATION OF EXPLOSIVE PROPELLANT MIXTURES.

REMARKS: Propellant logistics elements are designed to prevent restricted volumes.When they are enclosed in restricted volumes such as the cargo bay of the shuttle normal leakage will, in time, accumulate explosive mixtures. For this reason restricted volumes should be purged with an inert gas in sufficient volume to prevent the accumulation of hazardous concentrations of propellants (4% by volume of hydrogen). Further considerations would be the elimination of pockets or dead spaces that did not receive purge flow and the protection of pad personnel from suffocation from the large volumes of inert gas that would be required.

REFERENCES: HA 4, 46, 51, 52, 97, 120, 121, 161

CROSS REFERENCES: 6, 7

ISPSS GUIDELINE/REQUIREMENT

NO. 9

HAZARD GROUP: 1, 2

MISSION PHASE: Pre-launch, Orbital Operations

APPLICABLE SUBSYSTEMS: Facility and Vehicle Vent System

GUIDELINE TITLE: Expansion of Melting Solid Cryogen

STATEMENT: FACILITY AND VEHICLE VENT SYSTEMS MUST BE CAPABLE OF HANDLING LIQUID AND GASEOUS CRYOGENS.

REMARKS: The primary reason for considering the use of slush cryogens in propellant logistics is the density advantage. For instance, solid hydrogen is 22.4% more dense than an equivalent weight of liquid hydrogen. The design ullage for propellant modules is generally 5%. A prolonged delay in the launch or insulation loss leading to abnormally high heat leaks into the module will melt the solid fraction. The melting solid would expand and overflow the tank. A vent system would have to be provided to accommodate the liquid and attendant high volumes of gaseous propellant that would be produced. One pound of LH_2 forms 194.5 ft^3 of gas at 25° C and 1 atmosphere. Thus the volume change is approximately 860. This high volume flow in long vent lines could reflect high back-pressures into the propellant tank and over-stress the tank.

FIN 160

REFERENCES: HA5 (12), (13)

CROSS REFERENCES:

ISPSS GUIDELINE/REQUIREMENT

NO. 10

HAZARD GROUP: 2

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS: Propellant Tanks and Lines

GUIDELINE TITLE: **Solid/Liquid Separation in Slush** Cryogens

STATEMENT:
A MEANS MUST BE PROVIDED TO INSURE A UNIFORM MIXTURE OF THE LIQUID AND SOLID PHASE OF SLUSH PROPELLANTS DURING PROPELLANT TRANSFER.

REMARKS:
The solid particles of slush propellants are more dense than the liquid portion. Under the influence of gravity, the solid particles will settle to the bottom of the container and be the first available for withdrawing by the propellant transfer pumps. At the worst, this could lead to compaction or bridging of the solid particles and interruption or total blockage of the propellant flow and inability to control propellant flow. A total blockage of propellant flow would prevent off-loading propellants during an emergency, until heat-leaks melted the solid plug. At the least, a non-homogenuous mixture of solids and liquids would be transferred.

During ground loading this could lead to the inability to get enough solids in the propellant module to achieve the required solid fraction and possible compromise of the mission.

Solid/liquid separation could also occur when the flow velocity is not above a critical minimum and the solid particles settle to the bottom of the transfer line.

FIN 160

REFERENCES: HA 4, (52)

CROSS REFERENCES:

ISPSS GUIDELINE/REQUIREMENT

NO. 11

HAZARD GROUP: 2

MISSION PHASE: Pre-Launch, Launch, Orbital Operations

APPLICABLE SUBSYSTEMS: Propellant Management

GUIDELINE TITLE: Solid Fraction Measurement in Slush Propellants

STATEMENT:

A MEANS MUST BE PROVIDED TO MEASURE THE SOLID FRACTION OF SLUSH PROPELLANTS IN PROPELLANT LOGISTICS TANKS.

REMARKS:

The solid fraction of slush propellants will expand upon melting. Sufficient ullage volume will have to be allowed to compensate for this increased volume of liquid as the solid fraction melts from heat leaks.

If sufficient volume is not available to accomodate the expansion of melting solids the unscheduled release of liquid/solid mixture could effect vehicle stability, impinge on surfaces of other vehicles or obscure visual aids.

FIN 160

REFERENCES: (12), (13)

CROSS REFERENCES: 9, 34, 55, 58

ISPSS GUIDELINE/REQUIREMENT

NO. 12

HAZARD GROUP: 1

MISSION PHASE: Pre-Launch

APPLICABLE SUBSYSTEMS:

Propellant and Pressurization

GUIDELINE TITLE: Loading, Un-Loading Propellants

STATEMENT:

LIQUID OXYGEN SHALL BE LOADED INTO PROPELLANT LOGISTICS ELEMENTS BEFORE LIQUID HYDROGEN, FAIL-SAFE EMERGENCY UN-LOADING PROVISIONS SHALL BE INCORPORATED INTO VEHICLE AND FACILITY SYSTEMS.

REMARKS:

The sequence of loading propellants into a dual-propellant logistics module while in the cargo bay of the shuttle shall be LOX first, then liquid hydrogen. (Ref. 48)

Should an emergency, such as fire, arise while the transport vehicle is still on the pad it will be necessary to un-load propellants from the Propellant Logistics Module. Even though the propellants were loaded in series, emergency conditions could dictate that the propellants shall be un-loaded in parallel in order to save time. The un-loading system shall be designed to accomplish un-loading in the time-limits established by the performance of the same task on the transport vehicle. As the propellants are drained by gravity and tank pressure the displaced volume shall be replaced by a compatible gas at a pressure no greater than that to be used in ascent. If the emergency causes power to fail to the valves used for un-loading, tank pressurization and the provision of Ground Purge, 8, the system shall fail to a safe mode of operation.

REFERENCES: HA7 (48)

CROSS REFERENCES: 13, 48

ISPSS GUIDELINE/REQUIREMENT

NO. 13

HAZARD GROUP: 1

MISSION PHASE: Pre-Launch, Launch, Retrieval

APPLICABLE SUBSYSTEMS: Propellant, Pressurization

GUIDELINE TITLE: Negative Tank Pressure

STATEMENT: PROPELLANT TANK SYSTEMS MUST BE DESIGNED TO AVOID FAILURE FROM NEGATIVE TANK PRESSURE.

REMARKS:

During the pre-launch and launch preparations a planned or inadvertant propellant dump could lower the ullage pressure of the tank and lead to collapse of the tank structure if a fail-safe means of re-pressurizing the tank with a compatible gas were not incorporated. Tank collapse would dump large quantities of propellants into the cargo bay and cause the loss of the transport vehicle & crew by fire or explosion.

During the preparations for shuttle de-orbit the tank pressure of the module must be verified to be within structural limits of atmospheric pressure before committing to de-orbit. Tank collapse when the transport vehicle reaches the sensible atmosphere could cause massive leaks of hydrogen that would mix with atmospheric oxygen inside the cargo bay and be ignited by heat, shock, or catalytic action and lead to the loss of the transport vehicle and crew. If the tank pressure cannot be verified to be acceptable it shall not be returned in the transport vehicle.

FIN 160

REFERENCES: HA 1, 71, 85, 87

CROSS REFERENCES:

ISPSS GUIDELINE/REQUIREMENT

NO. 14

HAZARD GROUP: 1, 2

MISSION PHASE: Launch

APPLICABLE SUBSYSTEMS: Propellant and Pressurization

GUIDELINE TITLE: Sub-Orbital Abort

STATEMENT: IN CASE OF ORBITER SUB-ORBITAL ABORT THE PROPELLANT LOGISTICS ELEMENT SHALL HAVE THE CAPABILITY TO SAFELY DUMP PROPELLANTS TO MEET THE 40,000 LB. ORBITER LANDING LIMITATIONS IN THE MINIMUM TIME (ORBITER FLIGHT TIME) AVAILABLE FOR PROPELLANT DUMPING.

REMARKS:

In case of a booster failure prior to staging the orbiter must have intact abort capability. The orbiter has the ability to land with a 40 k Lb. payload. Heavier payloads can be landed with a reduced factor of safety. If the propellant logistics element is the orbiter cargo and weighs more than 40 K Lb. it must dump propellants to reduce weight. If the element contains both propellants or LOX only it would be preferable to dump LOX because it is more dense and incombustible. If the module contains hydrogen only and dumping is necessary the orbiter dump lines must be designed to prevent back-diffusion of atmospheric oxygen into the hydrogen lines/tanks. The orbiter flight attitude must be optimized to minimize the affect of the trailing, and probably burning, cloud of hydrogen. The time available for dumping, in the worst case, will be approximately 200 sec. This minimum time is established by the orbiter flight time between the beginning of the abort sequence and landing.

FIN 160

REFERENCES: HA 76, 77

CROSS REFERENCES: 12, 13, 48

ISPSS GUIDELINE/REQUIREMENT

NO. 15

HAZARD GROUP: 1

MISSION PHASE: Sub-Orbital Abort, Re-Entry

APPLICABLE SUBSYSTEMS: Vent/Dump System

GUIDELINE TITLE: Vent/Dump System

STATEMENT: FOR TRANSPORTING PROPELLANT LOGISTICS ELEMENTS WITHIN ITS CARGO BAY, THE ORBITER MUST PROVIDE A CLOSED VENT/DUMP SYSTEM WHICH TERMINATES OUTSIDE THE CARGO BAY AND WHICH IS COMPATIBLE WITH THE LOGISTICS ELEMENT.

REMARKS:

Tank vents systems must be provided for the elements that allow the tanks to vent outside the cargo bay. This venting system must be capable of passing the gas that might be generated in the propellant tanks without over-stressing the tank.

Under zero "G" conditions local hot spots could develop because of heat leaks through lost or damaged insulation. When the propellant tank again came under the influence of gravity while in the cargo bay the residual liquid propellants could contact the hot spot and rapidly flash into vapor. The vent valves and lines must be large enough to prevent this pressure increase from over-pressurizing the tank.

When the vehicle has common vent and dump line the line will be sized to permit dumping the required amount of liquid in the minimum amount of time available for dumping.

The line size to be installed will be governed by the maximum size required to vent the gases or dump the liquids, whichever is larger.

REFERENCES: HA 76

CROSS REFERENCES: 3, 4, 14, 28, 47, 48

ISPSS GUIDELINE/REQUIREMENT

NO. 16

HAZARD GROUP: 10

MISSION PHASE: Manned Orbital Operations

APPLICABLE SUBSYSTEMS: Life Support System (LSS)

GUIDELINE TITLE: Contamination of LSS

STATEMENT: THE LSS OF MANNED PROPELLANT LOGISTICS ELEMENTS SHALL NOT PRODUCE TOXIC PRODUCTS OR BECOME CONTAMINATED BY TOXIC PRODUCTS FROM EXTERNAL SOURCES.

REMARKS:

The life support system of orbital storage depots must be designed for long-term use, or periods of intermitten use over long periods. These systems must not generate within themselves products that would be harmful to man or be subject to the introduction of harmful products from sources external to themselves. Prior to the use or reuse of such a LSS it must be verified to be operable and capable of supporting the crew without introducing toxic products.

FIN 160

REFERENCES: HA33

CROSS REFERENCES: 56

ISPSS GUIDELINE/REQUIREMENT

NO. 17

HAZARD GROUP: 8

MISSION PHASE: EVA

APPLICABLE SUBSYSTEMS: Life Support

GUIDELINE TITLE: EVA Operations

STATEMENT: EVA SHALL BE MINIMIZED DURING ORBITAL PROPELLANT LOGISTICS OPERATIONS.

REMARKS:

Propellant logistics systems shall not be designed or operated to require EVA for mission completion.

As a critical part of the man/machine system the elements that deal with mans protection in the space environment should have the same or greater level of redundancy as other critical elements in this system. Such is not the case with elements associated with EVA. There is no second pressurized volume to which the man could retreat in the event the first volume (suit) loses oxygen pressure because of rupture, puncture, or rips or umbilicals becoming fouled or kinked on obstructions. The decision to go EVA should be made where the benefits to be derived are commensurate with the risk to the crewman.

REFERENCES: Study Ground Rules HA 70

CROSS REFERENCES: 18, 19, 60

ISPSS GUIDELINE/REQUIREMENT

NO. 18

HAZARD GROUP: 2

MISSION PHASE: Orbital Assembly, Orbital Maintenance

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Manned Activation

STATEMENT: PROPELLANT LOGISTICS ELEMENTS WHICH ARE DESIGNED FOR AUTOMATIC OPERATION SHALL INCLUDE PROVISIONS FOR LOCAL, MANUAL CONTROL DURING ACTIVATION, EMERGENCY OR MAINTENANCE.

REMARKS:

After the assembly of orbital storage facilities, or after maintenance of these facilities the initial operation shall be verified by using local control. If the operation to be conducted could introduce hazards to crewmen in the immediate vicinity, the control of this operation shall be exercised at a stand-off distance that is great enough to eliminate this hazard.

FIN 160

REFERENCES: HA60

CROSS REFERENCES: 53

ISPSS GUIDELINE/REQUIREMENT

NO. 19

HAZARD GROUP: 10

MISSION PHASE: Orbital Maintenance

APPLICABLE SUBSYSTEMS: All Maintainable Elements

GUIDELINE TITLE: Maintenance Crew Support

STATEMENT: PROPELLANT LOGISTICS ELEMENTS SHALL PROVIDE AN ENVIRONMENT WHICH CAN BE MADE HABITABLE IN ALL AREAS THAT CONTAIN COMPONENTS THAT ARE SUBJECT TO FREQUENT ORBITAL MAINTENANCE.

REMARKS:

To minimize the requirement for EVA, those components that have a high maintenance rate should be repairable in a shirtsleeve environment.

REFERENCES: HA60, Study Ground Rules

CROSS REFERENCES: 18, 21

ISPSS GUIDELINE/REQUIREMENT

NO. 20

HAZARD GROUP: 2

MISSION PHASE: Orbital Assembly, Orbit, Maintenance

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Propellant Logistics Element Attach Points

STATEMENT: POSITIVE ATTACH POINTS SHALL BE PROVIDED FOR INSTALLING A PROPELLANT LOGISTICS ELEMENT IN A CARGO BAY WHICH DOES NOT PERMIT ANY MATING MISALIGNMENT OF THE LINE INTERCONNECT FIXTURE.

REMARKS:

Precise alignment of the line interconnect fixture is necessary to ensure that fluid connectors are leak-free and electrical connectors make contact between the shuttle and propellant modules. Orbital re-adjustments of this fixed relationship shall be eliminated by providing fixed attach points.

FIN 160

REFERENCES: HA 64, 72, 90

CROSS REFERENCES:

ISPSS GUIDELINE/REQUIREMENT

NO. 21

HAZARD GROUP: 10

MISSION PHASE: Orbital Maintenance

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Maintenance in Restricted Areas

STATEMENT: NO ORBITAL MAINTENANCE SHALL BE CONDUCTED BY A SUITED CREWMAN IN VOLUMES THAT DO NOT ALLOW FOR HIS RAPID RESCUE

REMARKS:

Any orbital maintenance by a crewman in a suit must include the possibility of requiring his rescue. EVA is a critical operation and working in confined spaces exposes him to increased hazards. These confined spaces would include the interior of propellant tanks, locations between the shuttle cargo and the cargo bay walls, or any space where the crewman does not have freedom of movement when encumbered by his suit or could readily be rescued by his buddy.

FIN 160

REFERENCES: HA60

CROSS REFERENCES: 17, 19

ISPSS GUIDELINE/REQUIREMENT

NO. 22

HAZARD GROUP: 2	MISSION PHASE: Deployment, Retrieval

APPLICABLE SUBSYSTEMS:

All

GUIDELINE TITLE: Power Removal Prior to Connector Operation

STATEMENT: ALL ELECTRICAL POWER SHALL BE REMOVED FROM ELECTRICAL CONNECTORS AND FLUID PRESSURE SHALL BE REMOVED FROM FLUID CONNECTORS PRIOR TO ENGAGEMENT OR DISENGAGEMENT.

REMARKS:

Electrical Connectors:

Electrical power should be removed from the conductors at a connector to minimize the possibility of sparking, arcing or welding of contacts by inadvertent shorting, prior to connecting or disconnecting. A connector should not be used as a switch. The ground contact of connectors should be the first one made and the last one broken.

Fluid Connectors:

Fluid connectors of the quick disconnect type shall be of the self-sealing type to minimize leakage or spillage. Any fluid connection that is not of the self-sealing type shall not be broken when the line contains fluid.

FIN 160

REFERENCES: HA 63	CROSS REFERENCES: 63

ISPSS GUIDELINE/REQUIREMENT

NO. 23

HAZARD GROUP: 2, 10

MISSION PHASE: Deployment, Docking, Retrieval

APPLICABLE SUBSYSTEMS: Reaction Control Systems

GUIDELINE TITLE: Reaction Control Interface

STATEMENT: THE REACTION CONTROL SYSTEM OF THE PASSIVE VEHICLE SHALL BE DEACTIVATED OR INTEGRATED WITH THE ACTIVE VEHICLE AS SOON AS VEHICLES ARE CAPTURED DURING DOCKING.

REMARKS:

As the supplier and user vehicles become captured prior to rigidizing during docking, the two vehicles can affect each other's attitude. If the reaction control system of the passive vehicle is not deactivated or synchronized with that of the active vehicle, the two RCS's could oppose each other. This would lead to high structural loads, possible structural damage at the docking interface as well as rapid depletion of RCS propellants.

FIN 160

REFERENCES: (69)

CROSS REFERENCES: 31

ISPSS GUIDELINE/REQUIREMENT

NO. 24

HAZARD GROUP: 8

MISSION PHASE: Docking

APPLICABLE SUBSYSTEMS: Docking

GUIDELINE TITLE: Docking to Unstable Vehicles

STATEMENT: DOCKING SHALL NOT BE ATTEMPTED BETWEEN VEHICLES THAT ARE NOT STABLE IN RELATION TO EACH OTHER

REMARKS:

Docking mechanisms will be designed to accept a limited amount of linear and angular deviation between the docking axes of the two vehicles. Any attempt to dock two vehicles that are moving in relation to each other could exceed the linear and angular tolerance and result in accidental impact or failure to capture. Consideration shall be given to automatic control of docking (with manual override) with inhibit circuitry to prevent attempts to dock vehicles whose motion cannot be synchronized.

FIN 160

REFERENCES: HA17, 88, 96, 107

CROSS REFERENCES: 57

ISPSS GUIDELINE/REQUIREMENT

NO. 25

HAZARD GROUP: 12

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS:

Manipulators

GUIDELINE TITLE: Manipulator Operation

STATEMENT:

ENERGY LIMITING DEVICES SHALL BE INCORPORATED INTO MANIPULATOR POWER SOURCES. SYNCHRONIZED AND INDEPENDENT OPERATING CAPABILITY SHALL BE PROVIDED FOR DUAL MANIPULATOR USE.

REMARKS:

Manipulator operation will be a manually controlled operation. To prevent the introduction of moments great enough to cause vehicle instability the energy that can be imparted by the manipulator should be limited by limiting the closing velocity to be compatible with the mass of the vehicles involved.

When an element is being deployed out of the cargo bay by two manipulators they shall be synchronized to prevent the rotation of the element about its roll axis. When the manipulators are being used to soft dock two vehicles together they shall be capable of independent motion.

Propulsive vents on propellant modules shall be held closed while the module is on the manipulator arms (with the monitor observing tank pressure to correct over pressure) to prevent the propulsive effects of unscheduled venting which could cause impact between vehicles.

FIN 160

REFERENCES: HA 23, 24, 25, 36, 37, 56, 66, 78, 85, 91, 92, 97

CROSS REFERENCES: 49, 61, 62

ISPSS GUIDELINE/REQUIREMENT

NO. 26

HAZARD GROUP: 2

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: Engine, Capillary Devices

GUIDELINE TITLE: Operating With Slush Propellants

STATEMENT: PROPELLANT LOGISTICS SYSTEMS THAT UTILIZE SLUSH PROPELLANTS MUST BE CAPABLE OF OPERATING WITH VARYING SOLID FRACTIONS.

REMARKS:

Heat leaks into tanks will melt the solid fraction of slush propellants. The percentage of solid remaining will diminish from a maximum of approximately 50% to 0% as a direct function of time and heat flux.

Engine performance will vary if it is fed propellants whose solid content varies. Additionally, solid particles will block small engine orifices and could lead to local hot spots and overheating or engine loss.

The small openings of capillary propellant settling devices will be restricted or blocked by the solid particles in slush. For this reason capillary devices shall not be used with slush propellants.

FIN 160

REFERENCES: (76)

CROSS REFERENCES: 11

ISPSS GUIDELINE/REQUIREMENT

NO. 27

HAZARD GROUP: 2

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: Propellant Tanks

GUIDELINE TITLE: Evaporative Freezing of Bulk Liquids

STATEMENT: BULK QUANTITIES OF LIQUIDS SHALL NOT BE EXPOSED TO VACUUM FOR EXTENDED PERIODS.

REMARKS:

When liquids are exposed to pressures below the triple point pressure and the vent opening is below a limiting fraction of the liquid surface area, some liquid will evaporate and solidify a substantial portion of the remaining liquid. The solid will require an extended time to sublime if it remains in a vacuum, or if subsequently re-pressurized, will require an extended time to melt to a liquid. The presence of the undetected solid could create a hazard to subsequent operations such as maneuvers of re-entry.

FIN 160

REFERENCES: 17

CROSS REFERENCES: 55

ISPSS GUIDELINE/REQUIREMENT

NO. 28

HAZARD GROUP: 2

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: Vent Lines, Dump Lines

GUIDELINE TITLE: **Clogging of Manifolds With Frozen Propellants**

STATEMENT: **A MEANS SHALL BE PROVIDED TO PREVENT THE ACCUMULATION OF SOLIDIFIED PROPELLANTS IN VENT OR DUMP LINES DISCHARGING INTO VACUUM.**

REMARKS:

The discharge of liquids from vent lines into vacuum produces solids when a portion of the liquid evaporates and freezes the remainder of the liquid. These solids can build up around and restrict the exit area. Plugs can form if the flow is intermittent. When the liquid expands on freezing these plugs can completely block the line to subsequent flow.

FIN 160

REFERENCES: 20

CROSS REFERENCES: 48

ISPSS GUIDELINE/REQUIREMENT

NO. 29

HAZARD GROUP: 2

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS:

Fluid Systems

GUIDELINE TITLE: Ejected Material

STATEMENT: DIRECT IMPINGEMENT OF EJECTED MATERIAL ON VEHICLE SURFACES SHALL BE AVOIDED IN THE DESIGN AND OPERATION OF PROPELLANT LOGISTICS SYSTEMS.

REMARKS:

Products of combustion exhausted from RCS, GG and main engines; propellant, water and urine dumps; vented gases and leaking propellants are some of the contamination sources to be expected during orbital propellant logistics operations. The effluents from these sources characteristically expand radially outward at high velocities in a 180° flattened hemisphere and quickly condense into small particles. When these particles impinge on vehicle surfaces they can build up until sublimed by heat. This build up can block or restrict visual aids. On all vehicles the propulsive effect must be countered by the RCS, or the exits made non-propulsive. If propellants build up on returning modules or in the cargo bay, they could sublime and form explosive mixtures in the cargo bay on re-entry.

The thermal effects of direct plume impingement on vehicle surfaces can have catastrophic results. High temperature exhaust gases from RCS or other engines can destroy vehicle surfaces not designed to withstand these high temperatures. Cold vent gases or cryogenic liquids are other extreme conditions that can damage vehicle surfaces by thermal shock.

REFERENCES: (4A)

CROSS REFERENCES: 3, 30, 34, 46, 51, 56

ISPSS GUIDELINE/REQUIREMENT

NO. 30

HAZARD GROUP: 2

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: View Ports and Optical Lenses

GUIDELINE TITLE: Protection of Visual Aids

STATEMENT: **RETRACTIBLE SHIELDS SHALL BE PROVIDED FOR CRITICAL VISUAL AIDS THAT COULD BE SUBJECT TO CONTAMINATION OR METEOROID BOMBARDMENT**

REMARKS:

Venting or leaking fluids expand, at high velocity, radially outward from the source. These fluids quickly freeze into "ice" and adhere to surfaces they contact. To prevent this accumulation from restricting or blocking vision through viewports or TV lenses, these visual aids **shall be provided with retractable covers to be used to protect** them during periods when they could be obscured. Long term exposure to meteoroid bombardment could also reduce visibility and the shields **shall be used during high** density meteoroid showers.

FIN 160

REFERENCES: HA115

CROSS REFERENCES: 35,56

ISPSS GUIDELINE/REQUIREMENT

NO. 31

HAZARD GROUP: 2

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: Reaction Control System (RCS)

GUIDELINE TITLE: RCS Capability

STATEMENT: THE RCS OF PROPELLANT LOGISTICS ELEMENTS, OR COMBINATION OF ELEMENTS, SHALL BE CAPABLE OF MAINTAINING THE STABILITY OF PROPELLANT LOGISTICS ELEMENTS UNDER ALL CONDITIONS.

REMARKS:

The RCS is the prime means of establishing and maintaining the stability of orbital units or assembly of units. When the elements have been designed to be inherently stable there are forces that would tend to upset this stability if not counteracted by the RCS. Among these forces would be:

1. Docking impact
2. Fluid sloshing
3. Uncoordinated RCS action between docked vehicles
4. Propulsive venting
5. Propulsive effect of leaking propellants
6. CG migration
7. Dynamic coupling or overall vehicle dynamics
8. Intermittent propellant supply or lack of propellants to RCS

In the final design, all of these subjects shall be fully investigated and resolved in the design process.

FIN 160

REFERENCES: HA 17, 39, 41, 46, 99, 105

CROSS REFERENCES: 23, 32, 33, 34, 41

ISPSS GUIDELINE/REQUIREMENT

NO. 32

HAZARD GROUP: 2, 8, 9, 12

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: Shock Absorbers, Slosh Control, RCS

GUIDELINE TITLE: Uncontrolled Oscillations

STATEMENT: **WHEN PROPELLANT LOGISTICS ELEMENTS ARE JOINED OR BEING JOINED THE STABILITY OF THE ENTIRE CONFIGURATION SHALL BE CONTROLLED TO PREVENT DISTURBANCES WHICH ARE DETRIMENTAL TO THE SYSTEMS OR CREW.**

REMARKS:

Disturbances must not be allowed to build up to the point that human or systems performance is degraded. Some factors that would tend to cause disturbances are:

1. Docking impact - both momentum and resulting fluid excursion
2. Fluid sloshing
3. Uncoordinated RCS action between docking or docked vehicles
4. Propulsive venting
5. Propulsive effect of leaking propellants
6. C.G. migration
7. Dynamic coupling or overall vehicle dynamics
8. Intermittent, or depleted propellants to RCS

FIN 160

REFERENCES: HA 120, 166

CROSS REFERENCES: 31

ISPSS GUIDELINE/REQUIREMENT

NO. 33

HAZARD GROUP: 8, 12

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: Slosh Control

GUIDELINE TITLE: Fluid Sloshing

STATEMENT: SLOSH PREVENTING AND DAMPING DEVICES SHALL BE INCORPORATED INTO THE PROPELLANT TANKS OF PROPELLANT LOGISTICS ELEMENTS.

REMARKS:

Fluid sloshing under the conditions encountered in propellant logistics operations remains one of the largest contributors to vehicle instability. The design process must include a study of the ways that fluid sloshing is introduced and establish means to ensure that sloshing is not started or minimized and does not contribute to vehicle instability.

FIN 160

REFERENCES: HA4, 46, 51, 52, 97, 120, 121, 161

CROSS REFERENCES: 24, 25, 31, 39, 41, 42

ISPSS GUIDELINE/REQUIREMENT

NO. 34

HAZARD GROUP: 2, 9

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: Vents, Exhaust Outlets

GUIDELINE TITLE: Non-Propulsive Vents

STATEMENT: EXHAUST GAS AND TANK VENT OUTLETS OF PROPELLANT LOGISTICS ELEMENTS SHALL BE DESIGNED SO THAT THE PROPULSIVE EFFECT OF VENTING FLUIDS WILL NOT ADVERSELY AFFECT THE STABILITY OF THE ELEMENTS.

REMARKS:

The design process must evaluate the placement and pointing direction of venting fluids. The unscheduled propulsive venting of the tanks on a single element could impart an acceleration that would create vehicle instability, jeopardizing the trajectory of the element or causing impact on neighboring vehicles. When elements are joined for transfer the ejected materials could impact on visual aids and cause hazards to vision. During the docking operation propulsive venting could change the approach velocity and cause accidental impact or failure to capture.

FIN 160

REFERENCES: HA22, 125, 159

CROSS REFERENCES: 31

ISPSS GUIDELINE/REQUIREMENT

NO. 35

HAZARD GROUP: 8

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Orbiting Debris

STATEMENT: THE COLLISION OF PROPELLANT LOGISTICS ELEMENTS WITH SPACE DEBRIS SHALL BE AVOIDED BY THE CHOICE OF LAUNCH WINDOW AND ORBITAL FLIGHT PATH.

REMARKS:

Ground tracking radar information can provide a launch window to enable propellant logistics elements to be timed to miss space debris that is detectible by such radar. Once an element achieves orbit, the bigger it is and the longer it stays in orbit increases the probability of being struck and damaged by orbiting debris. Reference 12A, Volume III, Appendix H, cites a probability of 0.002 for a space station (approximately the size of a large storage facility) orbiting at a 200 nautical mile altitude being struck by debris of 5 feet to 30 feet in size within ten years. If other debris were included the probability would increase. The hazard of propellant logistics elements being struck by debris is a residual one and continued effort must be expended to reduce it.

FIN 160

REFERENCES: HA 15, 103, (12A)

CROSS REFERENCES: 36

ISPSS GUIDELINE/REQUIREMENT

NO. 36

HAZARD GROUP: 2

MISSION PHASE: Orbital Operations

APPLICABLE SUBSYSTEMS: All Exposed Elements

GUIDELINE TITLE: Meteoroid Shields

STATEMENT: METEOROID SHIELDS SHALL BE PROVIDED FOR CRITICAL COMPONENTS AND SYSTEMS OF PROPELLANT LOGISTICS ELEMENTS.

REMARKS:

The impact of meteoroids on propellant logistics elements can reach a high probability depending on orbital altitude, size of element, and orbital stay time. A meteoroid shield that will absorb the impact of meteoroids of one gram mass with velocities of 25 - 30 km/sec is considered the minimum protection for critical components.

FIN 160

REFERENCES: HA 14, 43, 153, 157, (12A)

CROSS REFERENCES: 30

ISPSS GUIDELINE/REQUIREMENT

NO. 37

HAZARD GROUP: 2

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS: User Propellant Tanks and Lines

GUIDELINE TITLE: Childown

STATEMENT:

THE USER PROPELLANT TANKS AND LINES **SHALL BE COOLED DOWN SLOWLY TO** REDUCE THE THERMAL SHOCK OF FULL CRYOGENIC FLOW.

REMARKS:

A sudden transition from a relatively warm, empty state to cryogenic temperatures could introduce stresses in the user propellant tanks or lines that would exceed their design limits. The results could be catastrophic and require the return of the vehicle for ground repairs.

FIN 160

REFERENCES: HA3, 133, 162

CROSS REFERENCES: 55, 56

ISPSS GUIDELINE/REQUIREMENT

NO. 38

HAZARD GROUP: 2

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS: Propellant Transfer Lines

GUIDELINE TITLE: Velocity Head Suppression

STATEMENT: A MEANS SHALL BE PROVIDED TO SUPPRESS VELOCITY HEAD DURING PROPELLANT TRANSFER OPERATIONS TO PREVENT OVER PRESSURIZATION.

REMARKS:

In the case of propellant transfer by pumping expulsion the sudden closure of valves in the discharge line could subject the discharge lines to pressures that exceed the design limit. To eliminate excessive pressure the design of the propellant transfer system should include some method of preventing this occurrence or absorbing it if it did occur. Electrical interlocks between the pump and valves would prevent this occurrence or surge chambers would absorb the pressure.

FIN 160

REFERENCES: (31)

CROSS REFERENCES: 29, 58

ISPSS GUIDELINE/REQUIREMENT

NO. 39

HAZARD GROUP: 2

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS:

Propellant Settling

GUIDELINE TITLE: Vapor Pull-Through

STATEMENT: **ANTI-VORTEX OR OTHER DEVICES SHALL BE INCORPORATED IN TANK OUTLETS TO MINIMIZE VAPOR PULL-THROUGH DURING PROPELLANT TRANSFER OPERATIONS.**

REMARKS: Vapor pull-through can introduce variations in propellant flow. Alternate liquid and vapor could be introduced into discharge lines and produce variations in residual propellants.

The performance of gas generators, pumps, RCS or other units that utilize propellants from the main tanks would be adversely affected by intermittent gas and liquid flow.

It is for these reasons that effective liquid/vapor interface control be implemented and vapor pull-through be minimized.

FIN 160

REFERENCES: HA 82, 119, 166

CROSS REFERENCES: 41, 42

ISPSS GUIDELINE/REQUIREMENT

NO. 40

HAZARD GROUP: 1

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS: Gas Generator

GUIDELINE TITLE: Gas Generator Safety Devices

STATEMENT: SAFETY DEVICES SHALL BE INCORPORATED INTO THE GAS GENERATOR OUTLET TO REDUCE OR TERMINATE PROPELLANT FLOW TO THE GG IF EITHER TEMPERATURE OR PRESSURE BECOMES EXCESSIVE OR UNSTABLE.

REMARKS:

Gas generators characteristically operate fuel-rich as compared to an engine designed to produce thrust. If the fuel supply is interrupted or reduced the output pressure and temperature go up. If the fuel supply is stopped the hot engine is quickly destroyed by oxidation.

FIN 160

REFERENCES: HA 48, 50, 118, 123

CROSS REFERENCES: 63

ISPSS GUIDELINE/REQUIREMENT

NO. 41

HAZARD GROUP: 2, 7, 8, 9

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS: Propellant Tanks

GUIDELINE TITLE: RCS & Gas Generator Propellant Accumulator

STATEMENT: A MEANS SHALL BE PROVIDED TO INSURE THE AVAILABILITY OF PROPELLANTS TO THE RCS AND GAS GENERATOR.

REMARKS: When the RCS or gas generator utilizes propellants from the main tank to produce thrust to settle the propellants under zero "G" conditions, liquid propellant will not be available or will be available intermittently on start-up. Accumulators, "start-boxes" or other devices shall be incorporated to insure the availability of liquid propellants at the device during start-up.

When RCS propellants are supplied from the main tanks propellant transfer to the user could deplete the main tanks and lead to the inability to maintain control of the vehicle because of the lack of propellants for the RCS.

FIN 160

REFERENCES: HA 45, 49, 117, 121

CROSS REFERENCES: 40

ISPSS GUIDELINE/REQUIREMENT

NO. 42

HAZARD GROUP: 2

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS: Propellant Transfer Pumps

GUIDELINE TITLE: Propellant Transfer Pumps

STATEMENT:

ORBITAL PROPELLANT PUMPS SHALL BE CAPABLE OF WITHSTANDING TWO-PHASE FLOW.

REMARKS:

Pumps that are used for orbital propellant transfer will be exposed to alternate gaseous and liquid propellants at the inlet of the pump. This condition will prevail at start-up and shut-down and could occur at intermediate intervals The pump should be designed such that it will withstand two-phase flow without affecting pump performance.

FIN 160

REFERENCES: HA 83

CROSS REFERENCES: 39, 41

ISPSS GUIDELINE/REQUIREMENT

NO. 43

HAZARD GROUP: 2

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS: Rotating Machinery

GUIDELINE TITLE: Rotating Machinery

STATEMENT:

ROTATING ELEMENTS SHALL BE LOCATED OR SHIELDED TO PREVENT DAMAGE FROM EXPLODING FRAGMENTS.

REMARKS: Rotating machinery, such as turbine wheels, could overspeed and explode when exposed to excessive propulsive energy due to control failure. Such rotating devices shall be located or shielded such that the fragments or shrapnel from this explosion will not damage adjacent components.

FIN 160

REFERENCES: HA 84

CROSS REFERENCES:

ISPSS GUIDELINE/REQUIREMENT

NO. 44

HAZARD GROUP: 2

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS: Capillary Devices

GUIDELINE TITLE: Capillary Propellant Settling

STATEMENT: CAPILLARY BARRIERS BE DESIGNED TO PROVIDE POSITIVE VAPOR-LIQUID SEPARATION AND BE STRUCTURALLY CAPABLE OF WITHSTANDING PROPELLANT SLOSHING AND THE IMPACT OF SOLID PROPELLANTS.

REMARKS: The capillary devices that must be placed in the propellant tanks to utilize this method of propellant settling are more fragile than other structural components of the tanks. Capillary screens and channels are subject to being blocked by solidified particles, and if the propellant pumps placed a large delta pressure across the screens, total loss or damage could result. This restriction could prohibit the use of slush propellants with capillary settling devices and place further restrictions on operations that would tend to form solid particles. If the tank pressure dropped below the triple point pressure, either deliberately or accidentally, solid particles or chunks would be formed that could cause structural damage to screens. In addition to damage caused by solid particles the capillary devices must be designed to resist the impact of sloshing propellants and "g" forces introduced by acceleration.

FIN 160

REFERENCES:

CROSS REFERENCES: 27, 39, 63

ISPSS GUIDELINE/REQUIREMENT

NO. 45

HAZARD GROUP: 2

MISSION PHASE: Propellant Transfer

APPLICABLE SUBSYSTEMS: Propellant Tanks and Lines

GUIDELINE TITLE: Strainers and Filters

STATEMENT: STRAINERS OR FILTERS SHALL BE PROVIDED UPSTREAM OF DEVICES OR COMPONENTS THAT COULD BE BLOCKED OR RESTRICTED BY SOLID PARTICLE CONTAMINATION.

REMARKS:

Contamination control shall be exercised to prevent the introduction of propellants that are contaminated beyond acceptable levels. The repetitive filling and draining of orbital elements could accumulate contamination that would exceed allowable levels. Components that contain small orifices, such as gas generators and RCS engines, shall be provided with filters that are capable of eliminating solid particles that could block these orifices.

FIN 160

REFERENCES: HA2, HA9, HA10, 22, 84

CROSS REFERENCES:

ISPSS GUIDELINE/REQUIREMENT

NO. 46

HAZARD GROUP: 2

MISSION PHASE: Retrieval

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Sublimation of Solid Propellants

STATEMENT: PROPELLANT MODULES THAT HAVE BEEN DE-PRESSURIZED TO VACUUM SHALL NOT BE RETURNED IN THE SHUTTLE AS LONG AS SOLID PROPELLANTS REMAIN IN PROPELLANT TANKS. SOLIDIFIED PARTICLES OF PROPELLANTS ON MODULE OR CARGO BAY SURFACES SHALL NOT BE DE-ORBITED, BUT DELAYED UNTIL SOLIDS HAVE SUBLIMED.

REMARKS:

Solidified propellants will sublime in a vacuum at a rate that is dependent on the heat input. The hazards involved with de-orbiting solidified propellants are associated with subliming inside the cargo bay during de-orbit and resulting in fire/explosion when mixed with atmospheric oxygen entering through the cargo bay vents. Additional risks are associated with larger chunks that could be formed inside propellant tanks that could damage or rupture the tanks during maneuvers and discharge more propellants inside the cargo bay.

To minimize the possibility of returning solidified propellants inside a module tank, the only feasible alternate is to leave the module in orbit until heat leaks through the insulation will liquefy or sublime the solids. The time to accomplish this would vary with the quality of the insulation and the amount of solidified propellant.

A visual inspection of the cargo bay will verify the presence of "ice" or "snow". If present the cargo bay could be oriented toward the sun and the solar heat flux of 442 Btu/ft^2 over an area 15 x 60 feet would dissipate approximately 1800 pounds of solidified hydrogen per hour.

FIN 160

REFERENCES: Vol. III Section 4.2

CROSS REFERENCES: 3, 27, 28, 30, 47, 48, 51, 55

ISPSS GUIDELINE/REQUIREMENT

NO. 47

HAZARD GROUP: 1

MISSION PHASE: Retrieval, Re-Entry

APPLICABLE SUBSYSTEMS: Propellant Tanks, Lines and Vents

GUIDELINE TITLE: Orbital Leak Checks

STATEMENT: LEAK CHECKS SHALL BE PERFORMED ON PROPELLANT LOGISTICS SYSTEMS TO VERIFY THAT LEAKAGE IS WITHIN TOLERANCE PRIOR TO FLUID TRANSFER OR PRIOR TO RE-ENTRY IN THE SHUTTLE CARGO BAY.

REMARKS:

A means of leak detection must be provided for all propellant containers and interconnections. These provisions shall be used prior to initiating propellant transfer in orbit and to eliminate the possibility of mixing propellants whose total pressure could reach 2 mm Hg to minimize the possibility of fire/explosion.

A propellant module to be returned shall be visually inspected for damage and the evidence of leakage, since orbital liquid propellant leaks are highly visible. The cargo bay shall be visually inspected for evidence of solidifed propellants that have been deposited by propellant leaks. If there is evidence of propellant leakage on the modules it shall not be returned by shuttle until the propellant leakage terminates. If solidified propellants are evident in the cargo bay the orbiter shall not re-enter until the solids have sublimed. After emplacement the connection between the module and shuttle shall be verified to be leak free and the module itself be free of leaks prior to re-entry.

FIN 160

REFERENCES: HA 73, 79, 90 (17), Ref. Vol. III Section 4.2.5

CROSS REFERENCES: 13

ISPSS GUIDELINE/REQUIREMENT

NO. 48

HAZARD GROUP: 1

MISSION PHASE: Re-Entry

APPLICABLE SUBSYSTEMS: Propellant and Pressurization

GUIDELINE TITLE: Orbital Propellant Dump

STATEMENT: PROPELLANTS SHALL BE DUMPED FROM PROPELLANT LOGISTICS TANKS PRIOR TO DE-ORBIT AND RE-ENTRY IN A MANNED VEHICLE.

REMARKS:

Instrumentation errors could lead to returning propellant logistics elements in the shuttle with an unknown quantity of liquid propellants remaining in the tank. To minimize the fire and explosion hazard to the orbiter and crew the propellants shall be dumped prior to re-entry. The landing weight of the element could exceed the 40 k lb. limitation imposed by the orbiter with an unknown quantity of propellants aboard. A tank rupture would leak to the loss of the orbiter and crew.

The residual propellants in the tanks shall be no greater than that amount which could be vented without over-pressurizing the tanks if all the liquid were suddenly converted to gas by contacting hot spots on the tank walls.

FIN 160

REFERENCES: HA 74

CROSS REFERENCES: 3, 12, 13, 14, 55

ISPSS GUIDELINE/REQUIREMENT

NO. 49

HAZARD GROUP: 2

MISSION PHASE: Manned Operations

APPLICABLE SUBSYSTEMS: Man

GUIDELINE TITLE: Crew Fatigue

STATEMENT:

DURING MANNED PROPELLANT LOGISTICS OPERATIONS NO CREW MEMBER SHALL BE PLACED IN A CONTROL SITUATION WHEN HIS RESPONSE HAS BEEN DEGRADED BY FATIGUE.

REMARKS:

It can be anticipated that many propellant logistics operations will demand long hours from orbiting crewman. Procedures shall be developed for such operations that will provide time for meals and rest such that when human control is necessary the crewman is alert and capable of responding.

REFERENCES: HA40

CROSS REFERENCES: 62

ISPSS GUIDELINE/REQUIREMENT

NO. 50

HAZARD GROUP: All

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Redundancy

STATEMENT: THE CAPABILITY SHALL BE PROVIDED FOR PERFORMING CRITICAL FUNCTIONS AT A NOMINAL LEVEL WITH ANY SINGLE COMPONENT FAILED.

REMARKS:

The single most prevalent preventive measure identified by the preferred hazard reduction method was some form of redundancy. Sixty-six identified hazards required redundancy to reduce their potential. These systems and the number of times they were identified included the following:

RCS	- 20
Communications	- 8
Docking Devices	- 8
Valves	- 8
ECLSS	- 5
Computer	- 5

Other systems that required redundancy to reduce the hazard potential were identified fewer than 5 times. It is evident that the provision of redundant systems elements is critically important for the continued function of propellant logistics systems.

FIN 160

REFERENCES: MSCM 8080
66 individual hazard analyses

CROSS REFERENCES: 31, 57, 59

ISPSS GUIDELINE/REQUIREMENT

NO. 51

HAZARD GROUP: 1

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: Potential Propellant Leak Points

GUIDELINE TITLE: Confined Compartments

STATEMENT: THE DESIGN OF PROPELLANT LOGISTICS ELEMENTS SHALL ELIMINATE THE POSSIBILITY OF MIXING PROPELLANTS IN ANY SPACE WHERE THE COMBINATION COULD REACH PRESSURES OF 2 mm Hg OR GREATER UNDER ANY COMBINATION OF LEAKAGE CONDITIONS.

REMARKS:

Reactions that result in fire/explosion in the oxygen-hydrogen system can be initiated when the percentage of hydrogen is 4 percent by volume or greater, when oxygen is 2 percent by volume or greater, and the local pressure is 2 mm Hg or greater. For this reason potential leak sources shall not be confined, but open to the ambient atmosphere. Unlike propellant leak sources shall be physically separated as far as possible. Tank vents of propellant logistics elements must be provided with a closed, leak checked, venting and dumping system that terminates in the ambient atmosphere outside the cargo bay.

REFERENCES: HA45, 115, 116, 163

CROSS REFERENCES: 3, 6, 7, 14, 28, 29, 46, 47, 48

ISPSS GUIDELINE/REQUIREMENT

NO. 52

HAZARD GROUP: 2

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Operations Monitor

STATEMENT: AN OPERATIONS MONITOR SHALL BE PROVIDED THAT IS AWARE OF THE STATUS OF ORBITAL PROPELLANT LOGISTICS OPERATIONS AND HAS THE CAPABILITY OF ASSUMING MANUAL CONTROL OF AUTOMATIC OPERATIONS.

REMARKS:

The man/machine interface is established by the operations monitor. Communications shall be established between the orbital element and a manned control station. The man shall be aware of the progress of events and have the ability to over-ride automatic operations and use his reasoning ability to safely by-pass interruptions and complete the mission. Procedures shall be developed to place the operations monitor in command that is closest to the operation under way. If a station keeping orbiter is present or during orbiter attached rotation the orbiter crew-man shall be in control. If no manned element is present in orbit adjacent to the operation in progress then a ground monitor shall be provided.

FIN 160

REFERENCES: HA 57, 58, 61

CROSS REFERENCES: 54, 63

ISPSS GUIDELINE/REQUIREMENT

NO. 53

HAZARD GROUP: 2

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Manual Override of Automatic Propellant Logistics Operations

STATEMENT: PROVIDE FOR MANUAL INTERRUPTION AND CONTROL OF AUTOMATIC PROPELLANT LOGISTICS FUNCTIONS.

REMARKS:

Fully automatic, local control of an operation as complex as orbital propellant transfer is within the state of the art. It is visualized, however, that failures of these automatic sequences will occur. When these failures occur the capability must exist to manually interrupt the automatic sequences to perform trouble shooting and analyses in order to complete the logistics mission.

REFERENCES: (71), (75)

CROSS REFERENCES: 52, 54, 57

ISPSS GUIDELINE/REQUIREMENT

NO. 54

HAZARD GROUP: 2

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Systems Interlocks

STATEMENT: INTERLOCKS SHALL BE PROVIDED TO PREVENT THE OCCURRENCE OF OUT-OF-SEQUENCE EVENTS THAT COULD LEAD TO SYSTEM DAMAGE BECAUSE OF INADEQUATE PREPARATION FOR SUBSEQUENT EVENTS.

REMARKS:

The successful completion of complex operations is the result of many discrete steps. Automatic or manual controls shall be implemented to insure that no essential step is omitted. Monitors shall be provided to insure that no critical manual steps are skipped. Where possible, automatic features shall be designed into propellant logistics systems to minimize the possibility of inadequate preparations.

The final operational mode and configuration shall be studied to preclude the possibility of translating a docked element before separation, of initiating propellant flow before childown, of attempts to engage line interconnect fixtures before retracting the meteroid shield, or any other manual or automatic step that could lead to systems damage.

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REFERENCES: HA 43, 145

CROSS REFERENCES: 52, 63

ISPSS GUIDELINE/REQUIREMENT

NO. 55

HAZARD GROUP: 2

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: Propellant Tanks

GUIDELINE TITLE: Monitoring Quantity of Propellants

STATEMENT: PROVISIONS SHALL BE INCORPORATED IN ALL PROPELLANT LOGISTICS STORAGE TANKS TO MEASURE THE QUANTITY OF PROPELLANTS IN THE TANK.

REMARKS:

The quantity of propellants in the tanks shall be known to the monitor for successful completion of propellant logistics operations. Dead reckoning will not provide an accurate account of the propellants available from the main tanks to the RCS to maintain vehicle stability for recovery by the shuttle after having discharged a partial load to a user. An accurate propellant measuring system in the supplier vehicle will provide a cross check in the user vehicle to verify that enough propellants are aboard the user to complete its mission.

In case a zero g propellant gaging system is not available, conventional gravitational techniques could be used, but would permit gaging only while the propellant is subjected to acceleration.

FIN 160

REFERENCES: HA 47, 83, 88, 119, 122, 165

CROSS REFERENCES: 3, 11, 12, 14, 27, 46, 48

ISPSS GUIDELINE/REQUIREMENT

NO. 56

HAZARD GROUP: 2, 3, 4

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Materials Compatibility

STATEMENT: MATERIALS OR COMPONENTS ADJACENT TO FLUID LINES OR CONTAINERS SHALL BE COMPATIBLE WITH LEAKING FLUIDS

REMARKS:

It can be expected sometime during the use of propellant logistics systems that leaks will develop. Any component or structural element that could be exposed to this leakage must be capable of withstanding the effects of the fluids that leak out, whether the leaks occur on the pad or in orbit. Consideration shall be given to the thermal shock of leaking cryogens, rapid oxidization of combustible materials by leaking oxygen, the thermal effects of leaking hydrogen that burns in the air, and the corrosive effect of leaking nitrogen tetroxide.

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REFERENCES: SPD-1A

CROSS REFERENCES: 29

ISPSS GUIDELINE/REQUIREMENT

NO. 57

HAZARD GROUP: 2

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Automatic Operation

STATEMENT: REPETITIVE PROPELLANT LOGISTICS OPERATIONS SHALL BE AUTOMATED.

REMARKS:

The performance of man is subject to individual variations. His response is dependent on his training, experience, emotional stability, the amount of rest he has been permitted, and others. Any operation that is repeated shall be studied for automation to prevent variable performance and relieve man for the role he performs best and for which he will be the most useful in propellant logistics operations, such as problem solving and corrective action.

REFERENCES: HA20, 29, 30, 32, 99, 101, 105, 107, 108, 112, 130, 133, 134, 145, 154, 162, 176 (75)

CROSS REFERENCES: 52,53, 63

ISPSS GUIDELINE/REQUIREMENT

NO. 58

HAZARD GROUP: 1

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: Propellant and Pressurization

GUIDELINE TITLE: Pressure Relief

STATEMENT: PRESSURE RELIEVING DEVICES SHALL BE INCORPORATED INTO CLOSED SYSTEMS THAT WILL RESTRICT THE PRESSURE OF THE SYSTEM TO DESIGN LIMITATIONS.

REMARKS:

Locked up gases can expand upon being heated and rupture the line or tank that contains them. Trapped cryogens will gasify upon being heated, with a volume change of approximately 800:1, and rupture their container. Therefore, each closed liquid container shall be provided with a pressure relieving device.

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REFERENCES: HA11, 63, 80, 82, 167

CROSS REFERENCES: 38

ISPSS GUIDELINE/REQUIREMENT

NO. 59

HAZARD GROUP: 11

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: Communications

GUIDELINE TITLE: Communications Blackout

STATEMENT: DURING THE ROTATION OF PROPELLANT LOGISTICS ELEMENTS, EITHER AROUND ITS OWN AXIS OR THAT OF THE EARTH, A MEANS SHALL BE PROVIDED TO ENSURE CONSTANT COMMUNICATION BETWEEN THE ELEMENT AND THE MONITOR.

REMARKS:

Successful mission completion demands the knowledge of system status aboard unmanned orbiting propellant logistics elements or assemblies. Prior to initiating propellant transfer, during the extended period of the propellant transfer and during the retrieval operation the monitor must be aware that the systems have been prepared for the next operation.

REFERENCES: HA 69, 104

CROSS REFERENCES: 52, 61, 63

ISPSS GUIDELINE/REQUIREMENT

NO. 60

HAZARD GROUP: 2	**MISSION PHASE:** All

APPLICABLE SUBSYSTEMS: All Operating Systems

GUIDELINE TITLE: Man-Compatibility

STATEMENT: DURING MANNED PROPELLANT LOGISTICS OPERATIONS NO ATTACHED ELEMENT SHALL DEGRADE THE MAN-RATING OF THE MANNED ELEMENT.

REMARKS:

Manned vehicles must be designed and operated with safety factors and levels of redundancy such that they can be classed as "man-rated." Unmanned vehicles will not necessarily be restricted to this degree.

Whenever an unmanned element is in close proximity to a manned element such as transport to orbit in the cargo bay of the shuttle or propellant transfer with orbiter attached the unmanned element shall be man-compatible by being designed or operated in a manner such that the man-rating of the orbiter will not be jeopardized.

Human factors shall be considered during the operation of manned propellant logistics systems, such as: the degradation of human performance while being rotated during rotational transfer for an extended period.

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REFERENCES: HA 146	**CROSS REFERENCES:** 49

ISPSS GUIDELINE/REQUIREMENT

NO. 61

HAZARD GROUP: 2

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: All Manual Operations

GUIDELINE TITLE: Crew Training

STATEMENT: PROGRAMS SHALL BE IMPLEMENTED TO TRAIN PROPELLANT LOGISTICS CREWMEN IN ALL MANUAL OPERATIONS

REMARKS:

All ground and airborne crew members shall be trained in all operations, normal and emergency, they are to perform. Trainers shall be developed to closely simulate the conditions to be experienced when performing the actual operation.

REFERENCES: HA21, 58, 59, 63, 64, 65, 86, 89, 94, 96, 124, 127, 132, 138, 172, 173

CROSS REFERENCES: 62

ISPSS GUIDELINE/REQUIREMENT

NO. 62

HAZARD GROUP: 2

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: All Manual Operations

GUIDELINE TITLE: Procedures Development

STATEMENT: ALL MANUAL OPERATIONS SHALL BE GUIDED BY WRITTEN PROCEDURES THAT INCLUDE NORMAL AND EMERGENCY OPERATIONS

REMARKS:

Procedures shall be developed that cover all manual operations. Safety precautions and emergency or back-out procedures shall be included in the text at the point at which they are applicable. A ground monitor that is not subject to other distractions shall use such procedures as check-off lists to ensure that no essential step performed in orbit is omitted.

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REFERENCES: HA21,29,36,52,58,59,60,61,62,63, 65,68,72,73,79,85,88,90,93,94,98,102,105,109, 111, 112, 118,119,124,126,127,129,130,132-138, 143,147,155-158,160,164,168,171,172,174, 176-179

CROSS REFERENCES: 52, 61

ISPSS GUIDELINE/REQUIREMENT

NO. 63

HAZARD GROUP: 2

MISSION PHASE: All

APPLICABLE SUBSYSTEMS: All

GUIDELINE TITLE: Malfunction Detection and Warning Devices

STATEMENT: DEVIATIONS OF NORMAL OPERATING CONDITIONS SHALL BE DISPLAYED TO THE OPERATIONS MONITOR.

REMARKS:

The design process shall include an evaluation of the malfunction detectors to be provided and the manner in which this information is to be displayed. Warning devices to be considered will include:

1. Over and under pressure
2. Over and under temperature
3. Over and under voltage
4. Operation on reserves
5. Operation on redundant systems
6. For time critical emergencies the provision of and initiation of automatic corrective action
7. Environmental conditions in LSS

FIN 160

REFERENCES: HA 33, 53, 55, 69, 72, 80, 100, 109, 114, 124, 125, 142, 157

CROSS REFERENCES: 6, 7, 54